RESEARCH ARTICLE

Operating Room Time Savings with the Use of Splint Packs: A Randomized Controlled Trial

Tyler A. Gonzalez, MD, MBA; Eric M. Bluman, MD, PhD; David Palms, BS; Jeremy T. Smith, MD; Christopher P. Chiodo, MD

Research performed at Department of Orthopaedic Surgery, Brigham and Women's Hospital, Harvard Medical School, Boston, MA, USA

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Abstract

Background: The most expensive variable in the operating room (OR) is time. Lean Process Management is being used in the medical field to improve efficiency in the OR. Streamlining individual processes within the OR is crucial to a comprehensive time saving and cost-cutting health care strategy. At our institution, one hour of OR time costs approximately $500, exclusive of supply and personnel costs. Commercially prepared splint packs (SP) contain all components necessary for plaster-of-Paris short-leg splint application and have the potential to decrease splint application time and overall costs by making it a more lean process. We conducted a randomized controlled trial comparing OR time savings between SP use and bulk supply (BS) splint application.

Methods: Fifty consecutive adult operative patients on whom post-operative short-leg splint immobilization was indicated were randomized to either a control group using BS or an experimental group using SP. One orthopaedic surgeon (EMB) prepared and applied all of the splints in a standardized fashion. Retrieval time, preparation time, splint application time, and total splinting time for both groups were measured and statistically analyzed.

Results: The retrieval time, preparation time and total splinting time were significantly less ($p<0.001$) in the SP group compared with the BS group. There was no significant difference in application time between the SP group and BS group.

Conclusion: The use of SP made the process of splinting more lean. This has resulted in an average of 2 minutes 52 seconds saved in total splinting time compared to BS, making it an effective cost-cutting and time saving technique. For high volume ORs, use of splint packs may contribute to substantial time and cost savings without impacting patient safety.

Keywords: Ambulatory surgery, Economics, Efficiency, Foot and ankle, Lower extremity, Operating room, Splinting

Introduction

Rising health care costs and decreased reimbursements are making improvements in hospital efficiency a high priority for many healthcare professionals (1). One method of analyzing hospital efficiency is to analyze operational flow of various processes within the hospital. Through analysis of these processes, errors, variability and inefficiencies can be identified and subsequently minimized (2).

The operating room (OR) is the most expensive and complex unit within the hospital when trying to improve efficiency (3). In an effort to improve efficiency within the OR, many studies have looked at different ways of improving OR throughput, decreasing total operating room time and increasing profitability (4, 5). Components such as first case start time, perioperative planning, arrival times of physicians, and turnover times have all been shown to be inefficient. If improved upon, each of these steps could theoretically decrease cost and time in the OR (2).

Corresponding Author: Tyler Gonzalez, Harvard Combined Orthopaedic Resident Program, Department of Orthopaedic Surgery, Brigham and Women's Hospital Foot & Ankle Center, 1153 Centre St. Boston, MA 02130, USA
Email: tagonzalez@partners.org

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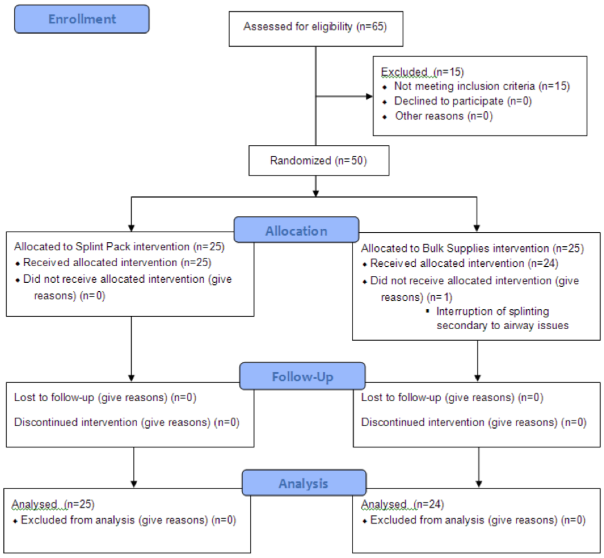

Figure 1. CONSORT Diagram.

New trends in analyzing operating room efficiency have emerged at several large academic institutions based on processes used by manufacturing companies to improve their efficiency. One of these is Lean Process Management (6). Non-lean processes are steps that waste time and provide no added benefit. Identifying these non-lean processes within the OR and making them "lean" is key to improving OR time, profitability as well as patient and staff satisfaction (3).

At our institution, one hour of OR time, exclusive of supply and personnel costs, is billed at approximately $500/hour. In many foot and ankle procedures a splint is applied after the completion of the case. This requires OR personnel to obtain the splint materials and bring them to the OR. The surgeon then prepares the splint from bulk supplies (BS) and applies the splint to the patient.

Commercially prepared splint packs (SP) contain all components necessary for plaster-of-Paris short-leg splint application and have the potential to decrease splint application time. We conducted a randomized controlled trial comparing OR time savings between SP use and BS application. This time saved with the use of SP may be of significant financial value and offset the difference in price between the SP and BS. We hypothesize that by using splint packs in the operating room there will be no time or cost savings compared to using bulk supply splinting material.

Material and methods

This study was conducted with Institutional Review Board approval and was registered with ClinicalTrials.gov (NCT01602484). We performed a prospective randomized controlled parallel-group study that took place in the operating rooms at a single hospital in the United States.

This is the first research done on the splint pack, so there were no previous studies to use to help estimate expected results. Surgeons in the main operating room where the studies were preformed use the splint pack as well as the standard bulk supply method to splint patients. To create an educated estimate of results, surgeons were surveyed in the OR regarding their estimated total time to splint a patient using both methods. Using these responses, it was estimated that it took ten minutes to splint a patient with the standard bulk supply method and surgeons estimate they save 30% of that time when using the splint pack. The effect size was calculated for the sample size by using expected control mean of ten minutes (600 seconds) with an estimated standard deviation of two minutes (120 seconds), and an expected test mean of seven minutes (420 seconds) with an estimated standard deviation of one minute thirty seconds (90 seconds). This calculation produced an effect size of 1.7. A stricter set of statistical standards was used to set the sample size calculation, setting alpha at <.01 and power at 0.9. This produced a sample size of approximately 15, which was then increased to the sample size of 25 patients in each study group to protect against subject dropout and increase the power of the results further.

Recruiting Patients

From November 2011 until May of 2012, 50 consecutive adult patients of the senior author's (EMB) surgical practice were enrolled. Inclusion criteria included patients who underwent operative intervention and on whom post-operative short-leg splint immobilization was indicated. Exclusion criteria included patients having medical conditions contraindicating splint application, a procedure for which short-leg splinting is not indicated, or occurrence of an unrelated medical event during splint application that disrupted continuous retrieval, preparation, or application. Patients meeting inclusion criteria and without exclusion criteria were randomized to either a control group using BS or an experimental group using SP prior to the start of the operative procedure. For randomization, simple randomization technique was used and preformed by the sealed envelope method. Each patient had a sealed envelope attached to his or her preoperative folder. Sealed envelopes contained either a splint pack or bulk supply label allowing for randomization. Prior to the start of the case the sealed envelope was handed to the primary surgeon and was opened to determine which splinting method would be preformed. Allocation was preformed based on the contents of the envelope. They were either allocated to the BS or SP group. Patients were blinded to the type of splinting method chosen. The senior surgeon was not blinded to the type of splinting method chosen as he had to determine allocation of the patients [Figure 1].

Splinting Technique

After randomization, a member of the operative team gathered splinting supplies from a plaster-cart that remained in a single location throughout the study period. The SP were manufactured and distributed by an independent company, Medline Industries Inc. None of the SP were created or altered by any member of the surgical or operating room staff. A SP contains the following

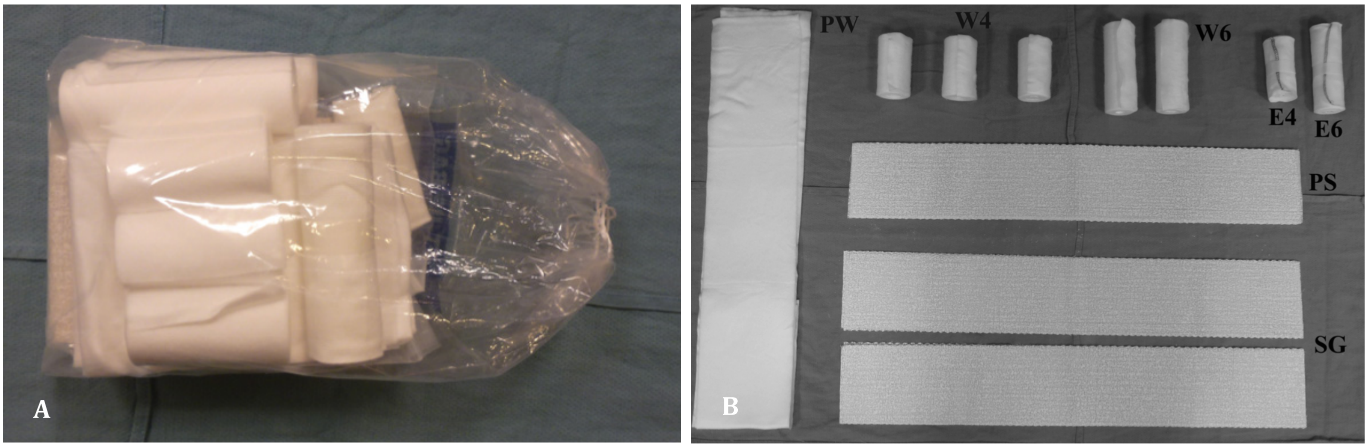

Figure 2. Commercially prepared splint pack. (A) Splint pack as it arrives in OR. (B) Components of splint pack laid out and organized for application. PW, 10 thickness 6" x30" posterior Webril padding; PS, 10 thickness 6" x 30" posterior plaster slab; SG, 5 thickness 6" x 30" plaster side gusset; E4, 4"elastic bandage, E6, 6" elastic bandage; W4, 4" Webril roll; W6, 6" Webril roll.

components: Three packs of 6 in. x 30 in. pre-cut plaster strips (one slab of ten thickness, two slabs of five thickness), 4 in. Webril undercast padding, two 6 in. Webril undercast padding, one 6 in. elastic bandage, and one 4 in. elastic bandage. These are prepackaged by the manufacturer and sent to us ready to use without any assembly needed [Figures 2A; 2B]. The BS splints were prepared to the same specifications using loose supplies found in the same plaster cart as the SP. For the BS splints plaster rolls were used to create plaster slabs. A laminated list was present on the plaster cart to ensure all components were collected during retrieval of BS. A single board-certified, fellowship-trained orthopaedic surgeon prepared and applied all of the splints in a standardized fashion (7).

Outcome Measurements and Statistical Analysis

Supply retrieval time, preparation time, splint application time for both groups were measured using a stopwatch. Supply retrieval time was measured as the time it took to gather supplies and return. Preparation time was measured as the time it took to organize all splint components so that no further modification was necessary prior to application (e.g. plaster slabs at appropriate length and elastic bandages unwrapped). Application time was defined as the time from the start of undercast padding application until the completion of elastic bandage placement over the plaster. Total splinting time was calculated as the sum of these times. Plaster drying time was not measured because water temperature, room humidity and standardization of plaster hardness could not be adequately controlled for between applications.

At the conclusion of enrollment, data were analyzed and statistical differences between the control and experimental groups were determined using a two-tailed Student's t-test. We used Cohen's d to calculate the effect size of the difference between the mean total splinting times of our two study populations. Cohen's d is defined as the difference between two means divided by a standard deviation for the data. According to Cohen's d values a value over 0.8 is defined as a large effect size where as one below 0.2 is a small effect size (8). The mean of the bulk supply group was 526 seconds with a standard deviation of 37 seconds. The mean of our splint pack group was 354 with a standard deviation of 34 seconds. These results produce a Cohen's d of 4.84, which is considered very large.

Sources of Funding

There were no external sources of funding for this study.

Results

During a six-month period from November 2011 to May 2012, 65 surgeries were performed at the study center. Of these, 15 were excluded from enrollment in the study. Reasons for exclusion were as follows: four required frequent wound checks, four underwent hip surgery, four underwent below-knee amputation, two underwent knee surgery and one patient did not require immobilization. Fifty patients met inclusion criteria, 29 females and 21 males. Twenty-five patients were randomized to each group. The SP group consisted of ten males and 15 females (mean age 58.2) and the BS group consisted of 11 males and 14 females (mean age 55.6)[Table 1]. No patient deviated from their original randomized group assignment. Data from one patient in the BS group was excluded from analysis because of an interruption of splint application secondary to airway issues. All patient demographic data and surgical procedures for both the SP and BS group are provided in [Table 1].

Statistical analysis revealed normal distribution of our data . Each of the three measured phases of splinting - retrieval, preparation and application - was analyzed as well as total time required for splinting. There was a significant difference in mean retrieval time between the SP group (33s±11s , 95% CI 29-37 s) and BS group (68 s±19s, 95% CI 61-76 sec). The mean preparation time also showed a significant difference between the SP group (1 min. 26 s±16s, 95% CI 1 min 20 s - 1 min 32 s) and BS group (3 min. 29 s±27s, 95% CI 3 min 18 s - 3 min 40 s). There was no significant difference in mean application time between the SP group (3 min. 55 s±21s, 95% CI 3 min 47 s - 4 min 4 s) and BS group (4 min. 9

s±21s, 95% CI 3 min 47 s - 4 min 4 s) and BS group (4 min. 9 s±29s, 95% CI 3 min 58 s - 4 min 21 s) [Figure 3]. No complications or adverse outcomes occurred in either group due to splint application.

For total time of the splinting process there was a significant difference in mean total time between the SP group (5 min. 54 s±34s, 95 % CI 5 min 41 s - 6 min 8

Table 1. Demographic data for SP and BS groups

SP Group Data		
Gender	Male	10
	Female	15
Age	Mean	58.2
Type of surgery preformed	1. Ankle arthroscopy with microfracture of talar dome	1
	2. Chronic achilles tendon repair with FHL transfer	1
	3. Tibial seasmoid resection	1
	4. Medializing calcaneal osteotomy+FDL to PT transfer+ strayer procedure	3
	5. Strayer procedure	1
	6. Ankle fracture ORIF	4
	7. Calcaneus fracture ORIF	3
	8. Tibiotalar arthrodesis	1
	9. Cheilectomy	1
	10. Lateral ligament reconstruction	2
	11. Wound I&D	1
	12. Talonavicular fusion + subtalar fusion	1
	13. Toe amputations	2
	14. Talar fracture ORIF	1
	15.Hammer toe correction	1
	16. Acute achilles tendon repair	1
BS Group Data		
Gender	Male	11
	Female	14
Age	Mean	55.6
Type of surgery performed	1. Medializing calcaneal osteotomy+FDL to PT transfer+ strayer	1
	2. Ankle fracture ORIF	5
	3. Calcaneus fracture ORIF	1
	4. Lateral ligament reconstruction	2
	5. Wound I&D	4
	6. Talonavicular fusion + subtalar fusion	2
	7. Acute achilles tendon repair	2
	8. Total ankle arthroplasty	1
	9. Tibiotalar + subtalar arthrodesis	2
	10. Subtalar fusion	1
	11. 1st MTP fusion	1
	12. Resection of Morton's Neuroma	1
	13. Removal of deep hardware about the tibia	1

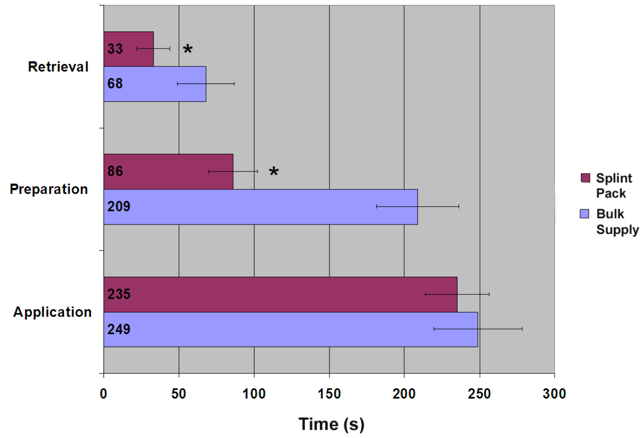

Figure 3. Graph showing the time, in seconds, taken to complete components of short leg splinting. Asterisk indicates a statistically significant difference between times for splint pack and bulk supply (*P*<0.001).

s±29s, 95% CI 3 min 58 s - 4 min 21 s) [Figure 3]. No complications or adverse outcomes occurred in either group due to splint application.

For total time of the splinting process there was a significant difference in mean total time between the SP group (5 min. 54 s±34s, 95 % CI 5 min 41 s - 6 min 8 s) and the BS group (8 min. 46 s±37s, 95% CI 8 min 32 s - 9 min 1 s) [Figure 4].

The effect size (calculated by using Cohen's d test) for total splinting time was 4.64. This correlates to a very large effect size. On average 2 minutes and 52 seconds or 23 dollars and 89 cents were saved per case when using SP compared to BS.

Discussion

In the past, health care efficiency has been studied by analysis of operational flow through different units of the hospital (i.e. emergency room, OR, outpatient clinics, etc.) in a linear fashion. When looking at improving OR efficiency, researchers have primarily focused on turnover time, operating room design and block time utilization (9, 10). Over the last decade, a new way of analyzing OR efficiency has emerged. Many researchers are now using analyses common in manufacturing industries to improve efficiency in the OR such as Lean Process Management, Six Sigma and parallel process systems (6,11,12).

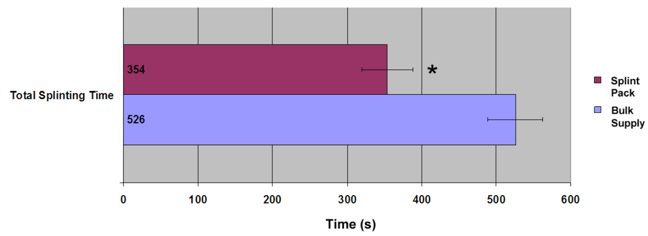

Figure 4. Graph showing the time, in seconds, for total splinting process. Asterisk indicates a statistically significant difference between times for splint pack and bulk supply (*P*<0.001).

Lean manufacturing management is a concept that arose in the 1990's for Toyota Production System (TPS). In part, through the use of lean processes to improve their efficiency, Toyota grew from a small company to the largest automaker in the world (13,14).

The philosophy of lean management is to preserve value while doing less work. Resources and time are carefully allocated to add value to the overall processes (9,15). Six Sigma originated from manufacturing companies and now this is a methodology used by many businesses to improve the quality of their process outputs. This is accomplished by identifying and removing the causes of defects (errors) and minimizing variability (16).

A recent study done at the Mayo Clinic using Lean Process Management and Six Sigma methodology looked at the process flow of the entire operative process from decision for surgery to discharge. The authors focused on minimizing volume variation, streamlining the preoperative process, reducing nonoperative time, eliminating redundant information and promoting employee engagement. They found that process redesign resulted in substantial improvements in on-time starts, reduction in number of cases that continued past 5pm and substantial increases in margins per OR per day (6). Collar et al. showed that by improving non-operative processes such as turn over time, through Lean Process Management, the annual opportunity revenue for the involved operating room was $330,000 (17).

Parallel process systems is another method by which efficiency can be improved and is now utilized by many surgical groups and hospital systems. Parallel processes refer to a group of tasks that are being accomplished at the same time in order to accomplish the same goal. For example, in a study by Smith et al. parallel process were investigated in an attempt to change throughput in their ORs. Their goal was to increase throughput of a single OR(preforming total knee arthroplasty) by using an induction room for administration of regional anesthesia, while the main OR was being prepared for the surgical procedure. Their results showed that a parallel processing system applied to appropriate operative cases resulted in approximately 50% reduction in non-operative time, a concomitant 12% reduction in operative time and this was all possible without extensive physical space redesign or capital investment (18). Another study by Friedman et al. showed that parallel processes can dramatically decrease induction time and turnover time, resulting in the potential for more surgical cases and increased revenue per OR per day (1).

Our study focused on a specific process, application of a postoperative short-leg splint in the OR. In many operating rooms, the process of applying a splint occurs in three phases: retrieval, preparation and application. Retrieval is when a member of the operative team gathers the materials needed to prepare the splint and brings them to the OR for the surgeon to use. Preparation phase occurs when the materials are organized into usable components. The final step is custom assembly of these components on the patient's lower extremity resulting in stable immobilization of their foot, ankle and leg.

Due to the variability of this process, the senior author decided to use commercially-prepared splint packs (SP) containing all components necessary for plaster-of-Paris short-leg splint application. Our goal was to decrease overall splinting time.

Looking at retrieval time our study showed that on average it took 35 seconds longer to gather the materials in the BS group compared to the SP group. The preparation time was over two minutes longer in the BS group, again providing a potential opportunity for time saving. When looking at all three processes, the total time saved in the SP group compared to the BS group was nearly three minutes per case. Splinting using bulk supplies wastes time without adding patient value.

At $500 per hour of OR time, three minutes of saved time amounts to $25 saved. The cost of the SP is ~$20 more than bulk supplies, so its use saves money on a per case basis. Use of SP is even more cost-effective if we consider the opportunity cost of the lost time per case. In high throughput orthopaedic surgery centers, a single foot and ankle surgeon may perform ten to 14 cases/day; the majority of which require splints. Our data show that one surgeon can save nearly three minutes per case by using SP. Over the course of a day in which ten surgeries are performed, as much as 30 minutes per day could be saved just by changing this one process. With this recouped time, surgeons could perform additional cases, advance their research, do administrative work, teach or take it for personal use.

We hope this study will encourage more surgeons to examine their OR practices and improve non-lean processes. Making large changes to improve efficiency has worked to some degree but problems with OR inefficiencies clearly still exist. By using lean process management and redesigning how OR processes are done, we can save time on simple processes that occur during almost every case.

Despite the prospective nature of this study there were obvious limitations. We realize that not all surgical specialties will use splinting during their procedure however the process of lean management will work in many surgical environments. For our study we focused on splint application in orthopaedic foot and ankle surgery. Other subspecialties using high throughput surgery centers, may realize comparable time savings if a high proportion of cases include splint application. We also realize that in lower throughput ORs saving minutes per case may not result in substantial time saved per day. However, using lean process management as a technique to improve efficiency should still be utilized by all ORs to identify processes, which they can improve.

We realize that circulating nurses multitask in the OR and in some cases can perform multiple tasks simultaneously (parallel processing). In low volume centers, circulating staff that are not heavily utilized may have the time to retrieve bulk materials for splinting. However the surgeon would still have to prepare the splints themselves which wastes valuable time. The highest value of the splint packs would be in high throughput ORs where utilization of OR staff is very high and staff members don't have time to retrieve the materials.

Despite the fact that the senior surgeon was not blinded to the splinting materials used, SP or BS, the surgeon did not alter his splinting technique as there was no significant difference in splint application time. Total splinting time was decreased due to a significant decrease in retrieval and preparation time while using SP compared to BS.

Improving efficiency and incorporating cost saving strategies are of great importance to both surgeons and hospital administrators. A novel approach to address these issues is to improve non-lean processes in the OR to increase financial returns as well as improve OR efficiency. We have used this approach to identify a non-lean process in foot and ankle surgery, total splinting time. Through the use of SP we have made this process lean. The use of SP is an improvement on a necessary procedure, that improves OR efficiency, saves times and has no change in patient outcomes or safety.

Conflicts of interests

There are no conflicts of interests or declarations from any author of the above manuscript.

Tyler Gonzalez MD, MBA
Harvard Combined Orthopaedic Surgery Resident PGY 3, Department of Orthopaedic Surgery, Massachusetts General Hospital, Brigham and Women's Hospital Foot & Ankle Center, Boston, MA

Eric M. Bluman MD, PhD
David Palms BS
Jeremy T. Smith MD
Christopher P. Chiodo MD
Harvard Medical School, Brigham and Women's Hospital Foot & Ankle Center, Boston, MA, USA

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